EARTHQUAKES IN AUSTRALASIA.—III.

BY GEORGE HOGBEN, M. A., TIMARU, NEW ZEALAND.

REFERENCE has already been made to the first report (1891) of the Seismological Committee of the A.A.A.S. (see *Science*, vol. XXI., p. 344), which, with a paper by the present writer, included summaries of all the known records of earthquakes in New Zealand to the end of the year 1890. The second and third reports of the same committee (1892 and 1893) have continued that work to the close of last year, and have added thereto similar summaries for New South Wales, Victoria, South Australia and the New Hebrides. The committee have also had placed at their disposal the observations (made under the direction of the late Captain Shortt, R.N., meteorological observer at Hobart, Tasmania) of a most remarkable series of shocks that occurred in Tasmania during the years 1883–1886. The large number of these shocks (2540) made it undesirable, if not impossible, to publish, even in a brief form, the details of each earthquake; but the chief results have been analyzed in two papers read before the last meeting of the Australasian Association; of these mention will be made below. The most interesting part of the last report (1893) is perhaps that containing the records from the New Hebrides. These consist of careful notes made by a missionary—the Rev. W. Gray—stationed at the Island of Tanna, and form the first fruit of our work in the Pacific, as distinguished from that on the continent of Australia and in New Zealand. Tanna contains one of the three active volcanoes in the group, and eruptions are frequent; nevertheless, though the volcanic and seismic phenomena are probably not unconnected, a large number of the earthquakes do not seem to have the characteristics of those commonly classed as volcanic. One feature of the earthquakes of the New Hebrides is the remarkable rise of land that has on several occasions been observed to follow the shocks. Darwin alludes, it may be remembered, to the recent elevation of these islands ("Coral Islands," chap. vi.); it is interesting to notice that they are still rising, and by no means at a slow rate. In Steel's "New Hebrides" it is stated that elevations of land took place after the earthquakes of Jan. 10, 1878, and Feb. 14, 1878, of twenty and twelve feet respectively; and further that "rocks which were formerly covered with seven or eight fathoms of water are now above high-water mark" (Steel, "New Hebrides," p. 189). The rise in the last two cases appears to have been local in nature, at least as regards the magnitude of the elevation. Here and there in books and papers upon the New Hebrides allusions less definite in character may be found to elevations of land in other islands, especially Aneityum. The Rev. W. Gray has supplied, in a letter accompanying his observations of the New Hebrides earthquakes, very definite details of elevations of land following two earthquakes, in 1888, which I believe have not before been placed on record, though they are quite as striking as the historical case noted by Darwin as having occurred on the coast of South America in 1835. On April 20, 1888, an upheaval took place at Tanna, exposing a new beach 58 yards in width. Mr. Gray says, "On examining this part I walked over ground dry-shod where a year ago I sailed in a boat and where at one time there was thirty feet of water."

The earthquake of June 24, in the same year, extended the beach another 97 yards seawards, the total width of new beach being 155 yards. Unfortunately Mr. Gray does not give the vertical height through which the coast was raised; but his description seems to imply a total upheaval for the two earthquakes of 40 feet at least. Near the middle of the beach last formed he marks a spot thus: "At this spot our mission-vessel lost an anchor more than ten years ago. It was brought up now."

The New Hebrides are cut off from the Loyalty Islands and New Caledonia by a narrow but deep trough in the ocean bed; yet some of the earth movements in these groups seem to correspond with one another. In the absence of more exact information it is premature even to hazard a conjecture; but should a sufficient correspondence be established, it would seem to show, (1) a deep-seated cause for the disturbances, (2) a general movement of that part of the floor of the Pacific Ocean. We hope to get evidence on these points shortly.

Two papers of mine read before Section A of the A.A.A.S. (Sept., 1893) dealt, the one with "Earthquake-Intensity in Australasia," the other with the "Tasmanian Earthquake of January, 1892." The former was suggested by a paper by Dr. Edward S. Holden, Director of the Lick Observatory, entitled "Earthquake-Intensity in San Francisco" (*American Journal of Science*, June, 1888). Dr. Holden gave therein the equivalents of the degrees of intensity of earthquake-shocks on the Rossi-Forel scale, in terms of the acceleration due to the velocity of the shock itself, expressed in millimetres per second; he then applied his table to form an estimate of the intensity of the shocks felt in San Francisco. I have done the same for the Australasian Colonies. For New Zealand we have for the years 1848–1892 the records of 926 earthquakes; but in the earliest years only the severest shocks were recorded, and until December, 1889, when the present system of observation through the officers of the Telegraph Department was begun, most of the shocks of intensity I. to III. on the R.-F. scale were probably neglected. Now comparatively few pass unnoticed; I have therefore taken the records for the three years, 1890–1892, only. The number of shocks is 198, and the mean average intensity per shock, as felt in New Zealand, is 72 m.m. per second, that is to say, between III. and IV. on the Rossi-Forel scale, or sufficient to make pictures move a little and to cause some doors and windows to rattle slightly.

For New South Wales (12 years) and Victoria (8 years) the average intensity is about IV.; but the records evidently omit nearly all the slighter shocks, and so this estimate is undoubtedly much too high. In South Australia, where somewhat fuller records were kept, the average intensity (10 years) is only a little over III. on the R.-F. scale.

The study of the remarkable series of earthquakes in Tasmania and southeast Australia, between April, 1883, and December, 1886, in conjunction with the determination of the origins of the principal shocks, opens up several questions of great importance, which it would take too long to discuss here. The total number of shocks for the 45 months was 2540, an average of 56.4 shocks per month, which would be sufficiently startling were it not that the average intensity of shock was only between III. and IV. (71 m.m. on the absolute scale). One month, October, 1883, enjoys the questionable distinction of having 231 shocks recorded against it, that is, seven or eight shocks a day; and November of the same year is not far behind. A second maximum of intensity was reached in August, 1884; and then a very gradual decline took place for nearly 2 1/2 years, the shocks slowly dying away at the end of 1886. The only considerable earthquake since then is that of January 27, 1892, felt all over Tasmania and in southeast Australia, for which the data were sufficient to determine the origin very nearly. It is situated below the deep trough of the Tasman Sea, about 353 miles east of Launceston and 365 miles from Hobart. The chief shocks of 1883–1886 may be referred with more or less probability to the same neighborhood; but many of the smaller shocks were more local. For 3 or 4 years a re-adjustment of the earth's crust was going on steadily; the larger shocks were perhaps merely in-

cidents caused by movements a little more rapid than usual, or by the sudden slipping of large masses out of the position of unstable equilibrium into which the slow movements had brought them. If these large or primary movements were fault movements, one would almost expect to find the axis on the edge, and not in the middle or at the bottom of a steep trough in the ocean-bed. If the primary movement, on the other hand, was principally one of revolution about the axis, interrupted by an occasional sliding of the mass on one side of the axis upon the mass on the other, then we must look for secondary movements at some distance from the axis, where the displacement caused by revolution is naturally greater. Is it possible that the lesser shocks were more or less local movements of this character? It is curious to notice that the total intensity of the series of shocks amounts to 186,690 absolute units, or about 19 times the acceleration due to gravity. The large expenditure of energy implied by this total suggests at least a possibility of a very appreciable amount of movement in the land-mass of Tasmania and southeastern Australia. Though, so far as I know, there is no evidence of elevation or depression, one does not like to think of Mother Earth wasting so much of her strength for naught.

LETTERS TO THE EDITOR.

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Volcanic Rocks in the Keewatin.

In view of the article published in *Science*, No. 571, entitled "Volcanic Rocks in the Keewatin of Minnesota," and the very numerous recent papers on the same subject, viz.: "Archæan Volcanic Rocks," it may be interesting to your readers, and, in any case, I think it is fair to myself, to publish the following letter of mine on the same subject, which was written fourteen years ago. Any comments by me are, I think, unnecessary.

Alfred R. C. Selwyn,
Deputy Head and Director,
Geological Survey Dept., Ottawa.

"Montreal, 9 December, 1879.

"My dear Professor Dana:

"I have just read your remarks[1] in reference to what I have ventured to call the Volcanic Group of the Quebec series of Sir W. E. Logan. I should like very much to know exactly what your views on this question are, and hope at some future time to hear them from yourself personally. In the meantime I would make a few explanatory remarks on the points you refer to in my paper. You say, 'The evidence of the general volcanic origin of the second group is not stated and the kind of rocks mentioned make a remarkable assemblage to be spoken of as these volcanic rocks.' This would seem as if I had meant to assert that all the rocks mentioned as constituting the group were of volcanic origin. I might certainly have made the matter plainer had I specified those rocks in the group which there were reasons for supposing to be of volcanic origin. It never occurred to me, however, that in giving a general description of a group of strata[2] of mixed volcanic and *ordinary* sedimentary origin it would be necessary to do so. As regards the evidence of a volcanic origin, of some of them I can only say now that it is of precisely the same kind as that which, in respect of similar British strata, has been considered to be conclusive by almost every British geologist of note, including De la Beche, Lyell,[3] Murchison, Sedgwick, Jukes,[4] Scrope and a host of others now living.[5] Further, that these conclusions, first arrived at by the most careful and minute geological investigations and mapping of the stratigraphy, have been, or are supposed to be, entirely confirmed by the, comparatively recent, microscopical and chemical investigations of these same rocks.

"It is now rather more than thirty years since I took an active part, under the geologist I have first named, in working out in all their intricate details the great Lower Silurian and Cambrian and older volcanic series of north Wales. Since then I have had abundant and world-wide opportunities of studying volcanic formations of all ages, recent, Tertiary, Mesozoic and Palæozoic, and I may say that it is on the result of this world-wide geological investigation and experience, and not on the occurrence of labradorite or any other particular mineral, that I have come to the conclusion that we have in Canada, as in Great Britain and elsewhere, good evidence of the existence of volcanic strata, and consequently of volcanoes, in Silurian or Cambrian and pre-Cambrian epochs. I am quite aware that most of the peculiar rocks, which, in common with a majority of British and some American geologists, I hold to be of volcanic origin, have heretofore been generally, and doubtless quite correctly, described simply as 'crystalline,' 'metamorphic,' or 'igneous' rocks. But this, it seems to me, does not refer so much to the question of their origin, as it does to that of their present condition and character, and if we carefully study their stratigraphical relations in the field, and their microscopic and physical characters, we at once find—at least, such has been my experience—that some other explanation of their origin and associations is required besides that of their being ordinary sedimentary deposits in a metamorphic condition. Indeed, your own and Mr. Hawe's careful and admirable investigations of the chloritic formation in the New Haven region seem to me to demonstrate the entire probability, to say the least, of the igneous and volcanic origin of the rocks you describe. It is, I believe, generally admitted that rocks having the mineral and physical peculiarities characteristic of many volcanic products would be more easily affected by metamorphic agencies, especially hydration, than those which are of ordinary and unmixed sedimentary origin and that these old volcanic rocks should have assumed these metamorphic or altered characters is, of course, what might be expected and their having done so certainly does not negative the supposition of their volcanic origin. It seems to me that *à priori* probabilities of the existence of volcanoes in Eozoic and Palæozoic epochs are very strong and that those who oppose any such idea should be prepared, like those who hold the opposite opinion, to state some good reason for their views, and also the particular geological epoch when, in their opinion, volcanic outbursts first occurred. If, on the other hand, the existence of volcanoes in these early geological epochs is admitted, then we may very naturally expect to find their products associated with the ordinary sedimentary rocks of the period, in the same manner as we do those of the volcanoes of recent and Tertiary times. And this is what British geologists generally claim to have done. I have no wish to dogmatise on this question and only desire the truth, whatever that may be; but at present I cannot help feeling that if I am in error, I am so in very excellent company, and that the views of such eminent geologists as I have named, and based, as I know

[1] *American Journal of Science*, vol. xv., 1879.
[2] Now, 1891, appropriately termed "*pyroclastic*."
[3] *Vide* Lyell's "Elements of Geology," 6th ed., pp. 695, 693.
[4] *Vide* Juke's "Manual," 2nd ed., p. 324.
[5] *Vide* Ramsay, "Memoirs," Geological Survey of Great Britain, vol. iii., chap. 5.